Multipathway Exposure Assessment

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Definition

- Direct Exposure: When exposure occurs to the contaminant in the media to which it is first released from the source.
- Multipathway/Indirect Exposure: When exposure occurs to the contaminant after it has crossed into different media.
- Features:
  - Most often applied to air toxics that are known to bioaccumulate in terrestrial and aquatic animals.
  - Inhalation is the direct pathway and soil/water/fish/terrestrial animal food pathways are the indirect pathways.
  - Often termed, Persistent and Bioaccumulative Toxics, or PBTs.
  - Indirect exposure can be 10 to 1000 times higher than direct exposure.

Overview

- History and Key Documents
- Fate Modeling
- Exposure Assessing
- Example

History

- 1990: Methodology for Assessing Health Risks Associated with Indirect Exposure To Combustor Emissions
  - Authored by NCEA- Cincinnati, this methodology document provided the first comprehensive set of fate equations and exposure methods for indirect pathways
- 1992: First Public Review Draft of Dioxin Reassessment Document
  - In an evaluation of potential incinerator impacts, the exposure to beef exceeded by inhalation by 4 orders of magnitude (a factor of 10,000)

History

- 1993: Waste Technologies Incorporated (WTI) Seeks Trial Burn for Permitting
  - Located in a river valley 100 m from elementary school, this state-of-the-art hazardous waste incinerator polarizes the issue as opponents cite 10,000 factor
  - EPA prominent scientist Lorber is called as hostile witness in attempted injunction against trial burn
- 1993: Carol Browner Issues 18-Month Moratorium on Permitting of Hazardous Waste Incinerators
  - OSWER implements interim guidance requiring hazardous waste incinerators to conduct comprehensive risk assessments for indirect impacts based on “Addendum” document

History

- 1994: SAB reviews "Addendum" to 1990 Methodology Document
  - "The model is an effort that pushes at the very edge of our current scientific knowledge. This is the source of its considerable merit, but it is also the ***source of its most serious limitations***."
  - NCEA-Cincinnati takes on the task of updating 1990 document including the Addendum with SAB inputs.
- 1994: EPA Region 4 Issues Emergency Action to Require Columbus Municipal Solid Waste Incinerator to Install MACT
  - Justification is an NCEA-Washington indirect risk assessment showing that extreme dioxin emissions result in an unacceptable risk to nearby home consumption farming families.

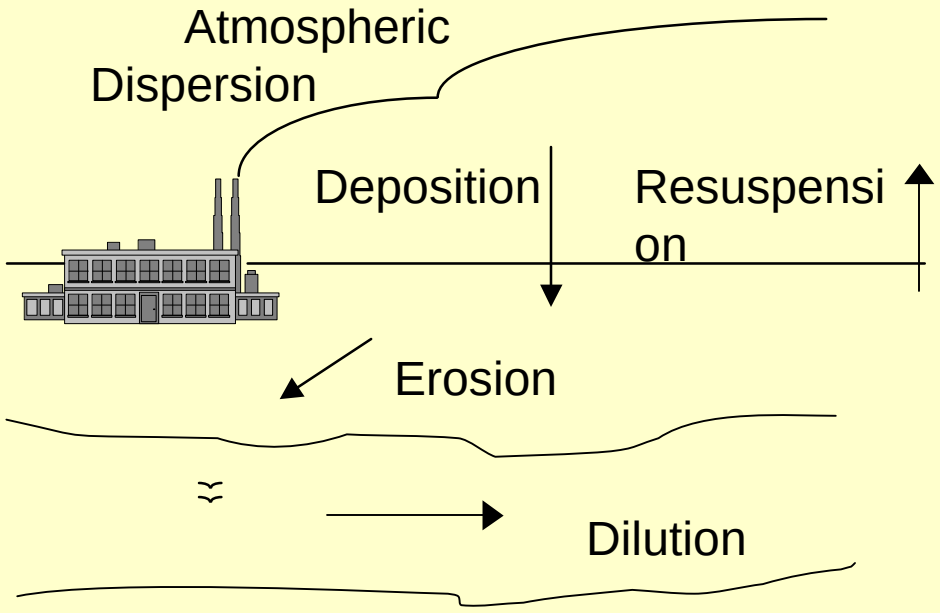
History

- 1994: Next Dioxin Draft Reassessment
  - Model refinements suggest that the disparity between inhalation and beef consumption is about a factor of 1,000 rather than 10,000
  - SAB review finds little to comment on for exposure assessment documents, but comments on health risk assessment, sending EPA back to the drawing board for another 6 years.
- 1997: Mercury Report to Congress
  - Comprehensive, landmark document including an exposure assessment conducted by NCEA-Cincinnati. Fate modeling from incinerator to fish highlights the complexity in modeling the impacts of this bioaccumulating inorganic

History

- 1998: Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities
  - Region 6 and OSW methodology document for evaluating direct and indirect impacts for HWCF
- 1998: Multiple Pathways of Exposure Document
  - NCEA-Cin Update to 1990 document
- 2000: Draft Dioxin Reassessment
  - Will it ever end?

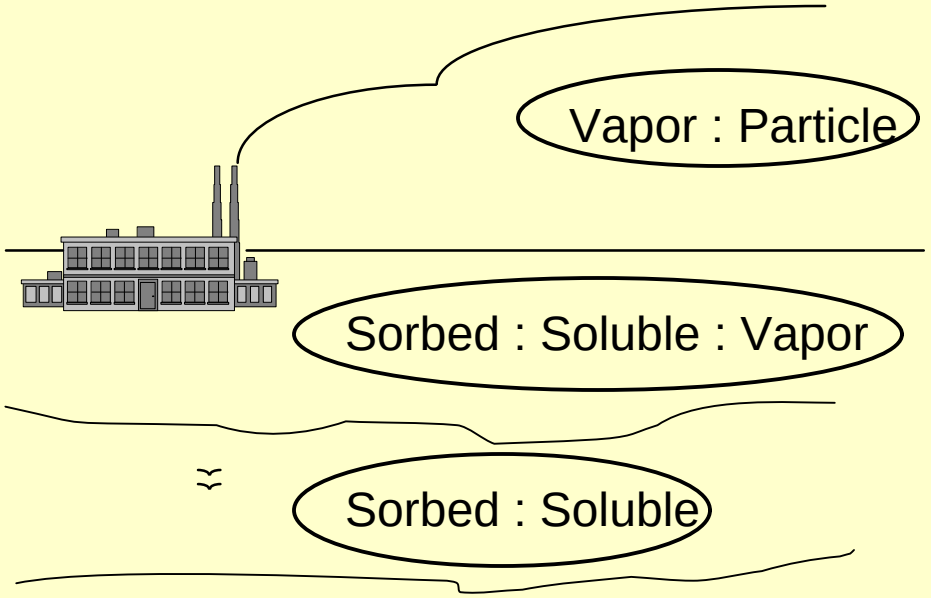
Models - Fate and Transport



- Fate and transport models are used to predict the movement of contaminants between and within compartments

- Examples: Erosion and Surface Water Dilution:
  - erosion and sediment delivery: [R * K * LS * C * P] * SD
  - simple dilution model: $C_{WATER} = \frac{Flux}{Flow}$

Models - Partitioning



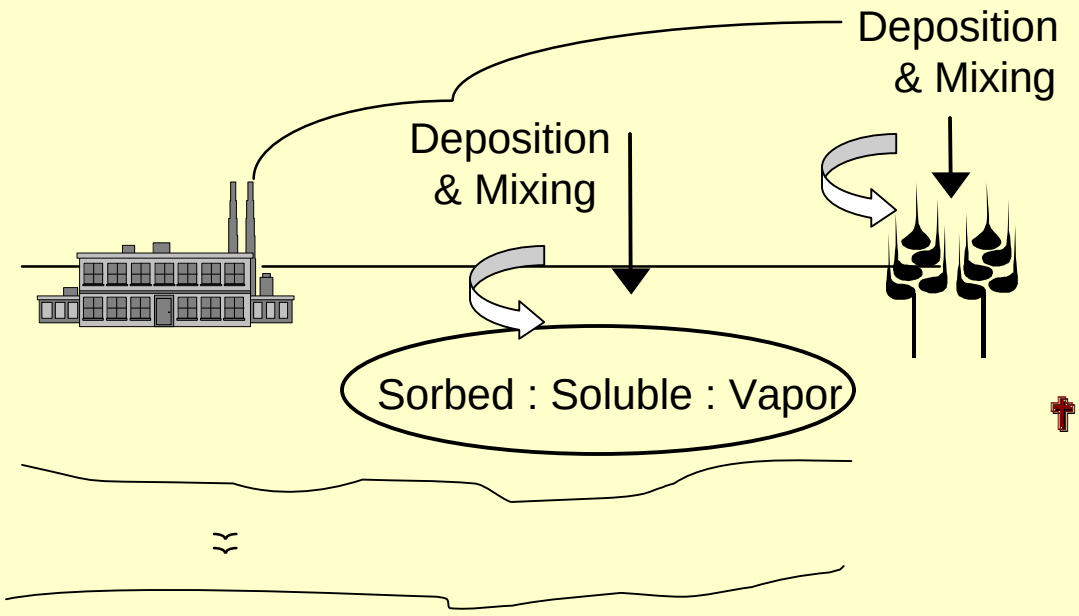
- Partitioning Models describe how contaminants "partition" between media in a particular environment
  - Dioxins, e.g., tend to sorb to soil/sediment and not exist to any significant extent in soluble phase. Lower chlorinated dioxins do exist in vapor phase.

- Example: Water Body Partitioning

$$C_{WATER} = C_{SORB} + C_{SOL}$$

$$KD_{WATER} = C_{SORB} / C_{SOL} = Koc * OC_{SED}$$

Models - Mixing

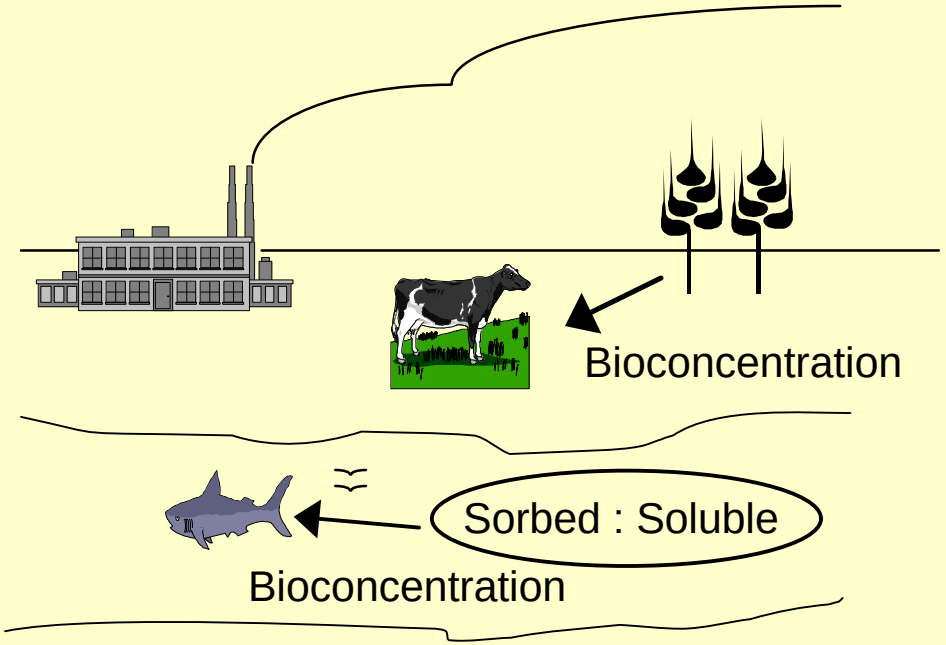


- Mixing Models are used to predict the concentration in a receiving stationary media compartment

- Example: Soil Mixing Model

$$C_{SOIL} = \frac{\text{Flux}}{K * \text{Mass}}$$

Models - Bioconcentration

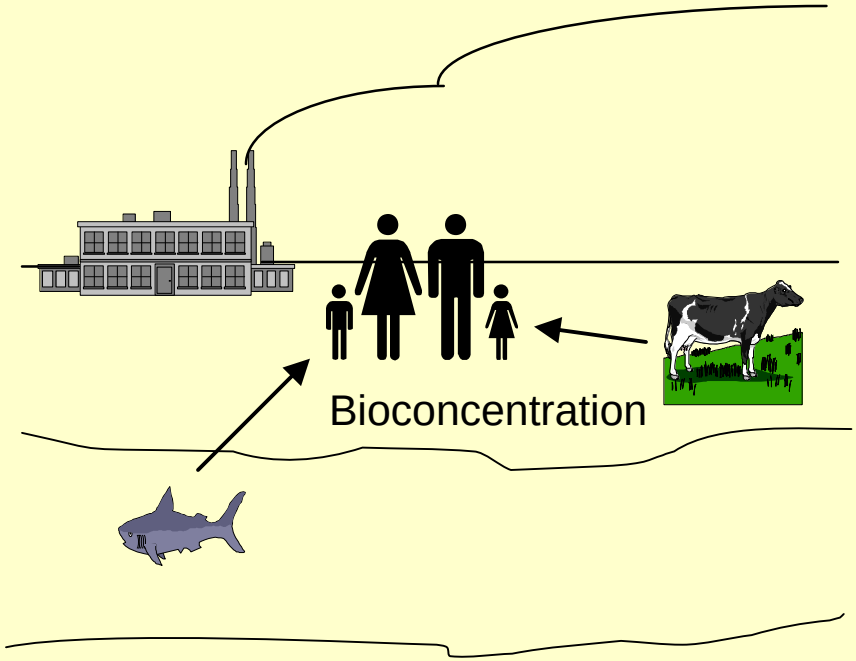


- Example: Fish Concentration

$$C_{LIPID} = BSAF * C_{SED}$$

- Bioconcentration models predict animal concentrations as a simple linear product of food or media concentrations and a "BCF". Biotransfer, or "BTF", models take a mass of contaminant and convert it to a concentration.

Models - Human Bioconcentration



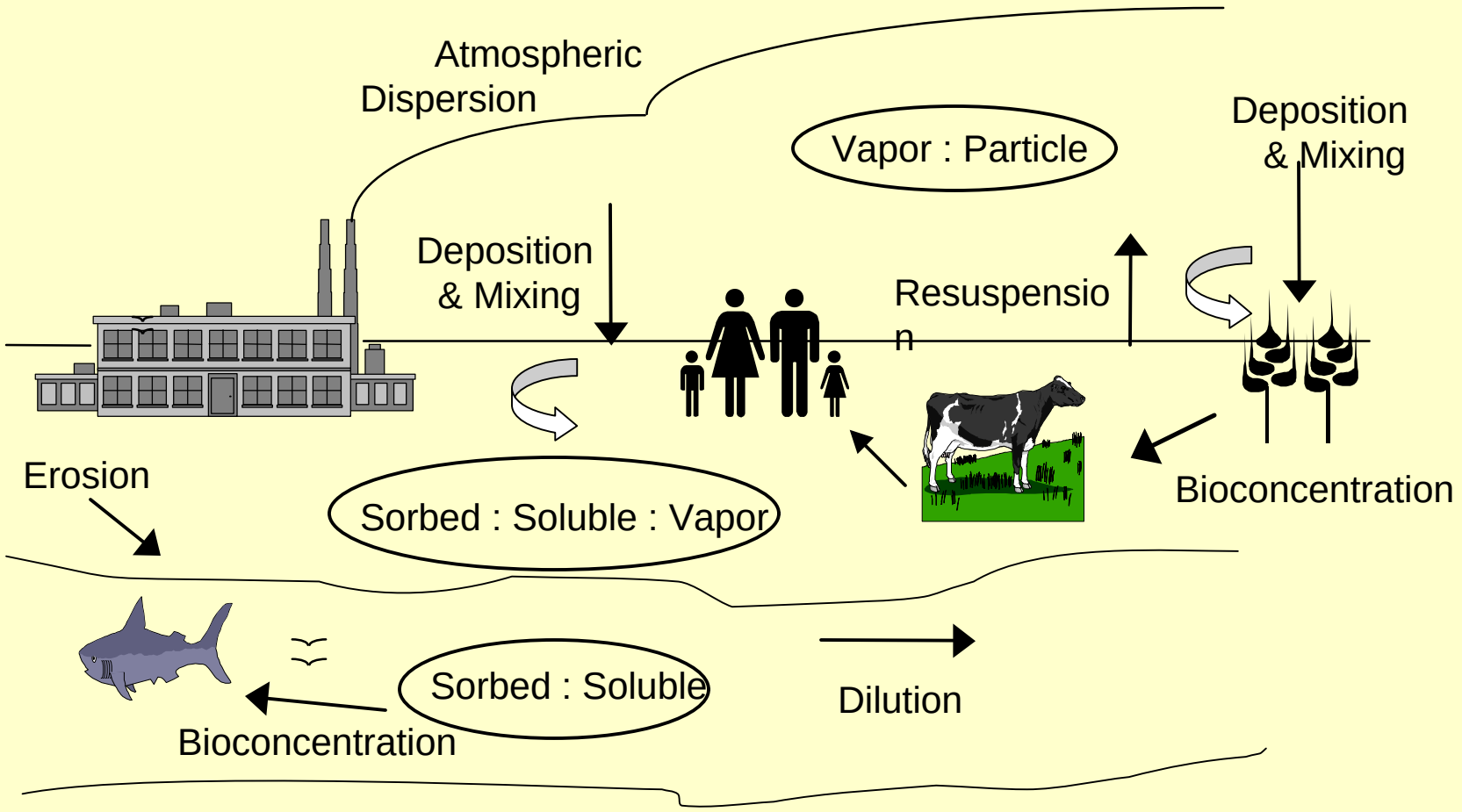
- PBTs not only bioaccumulate in animals, but also in humans. Simple models take a PBT intake dose and convert it to a body lipid concentration. This approach has been used for the breast milk pathway.

- Example: Simple Mixing Model

$$C_{Milkfat} = \frac{Intake * abs}{K * bodyfat}$$

Note: for long-lived lipophilic PBTs, assumes steady state and equal partitioning to all fat reservoirs

Models - Summary



Exposure Scenarios

- Farm Family
  - The family who consumes a portion of their homegrown produce. Typically, limited to one or two foods (beef/milk), but some have also added poultry, pork, and game to this scenario.
- Subsistence Fisher:
  - Not exposed to impacted terrestrial animals, but rather to fish from impacted water body
- Home Gardener:
  - Chosen as the “baseline” or “background” scenario.

Pathways and Issues

- Terrestrial Animal Consumption
  - "home producer consumption rates"; contact fraction
  - long term consumption with short term surveys
  - cooking losses, trimming fat, other practices
- Soil Pathways
  - dermal impacts from home gardening
  - child soil ingestion using surface soil concentrations
- Breast Milk Pathway
  - very important for lipophilic organics
- Others
  - don't forget inhalation
  - deer hunter, free range poultry, others?

Example - Columbus Incinerator

- June, 1983: The Columbus Waste to Energy Facility (WTEF) begins operation. The facility has six boilers, three stacks, and an average wasteload of 1600 t/day

- August, 1992: Emission tests for dioxin indicate emission concentrations averaging 13,000 ng total dioxins/m^3 , high > 17,000. Calculations suggest total loading from Columbus WTEF is 980 g TEQ/yr.
  - EPA 1995 Dioxin Inventory compiles known source emissions of 3000 g TEQ/yr (not including Columbus)

- Jan - June, 1994. Actions taken designed to reduce dioxin emissions; a stack test in March indicates that emissions of dioxin TEQs are reduced by about 75%.

Example - Columbus Incinerator

- June-August, 1994. Headquarters ORD and Region 5 conduct screening assessment of indirect impacts.

- September, 1994. Region 5 invokes Section 7003 of RCRA requiring MACT controls operational by January 1, 1997. Finding under Section 7003 is that continued emissions from the incinerator "may pose an imminent endangerment to the public health and the environment." Principal support includes: emissions data, dioxin reassessment (health findings), screening assessment.

- December, 1994. Columbus incinerator shuts down

Example - Columbus Incinerator

- FATE MODELING

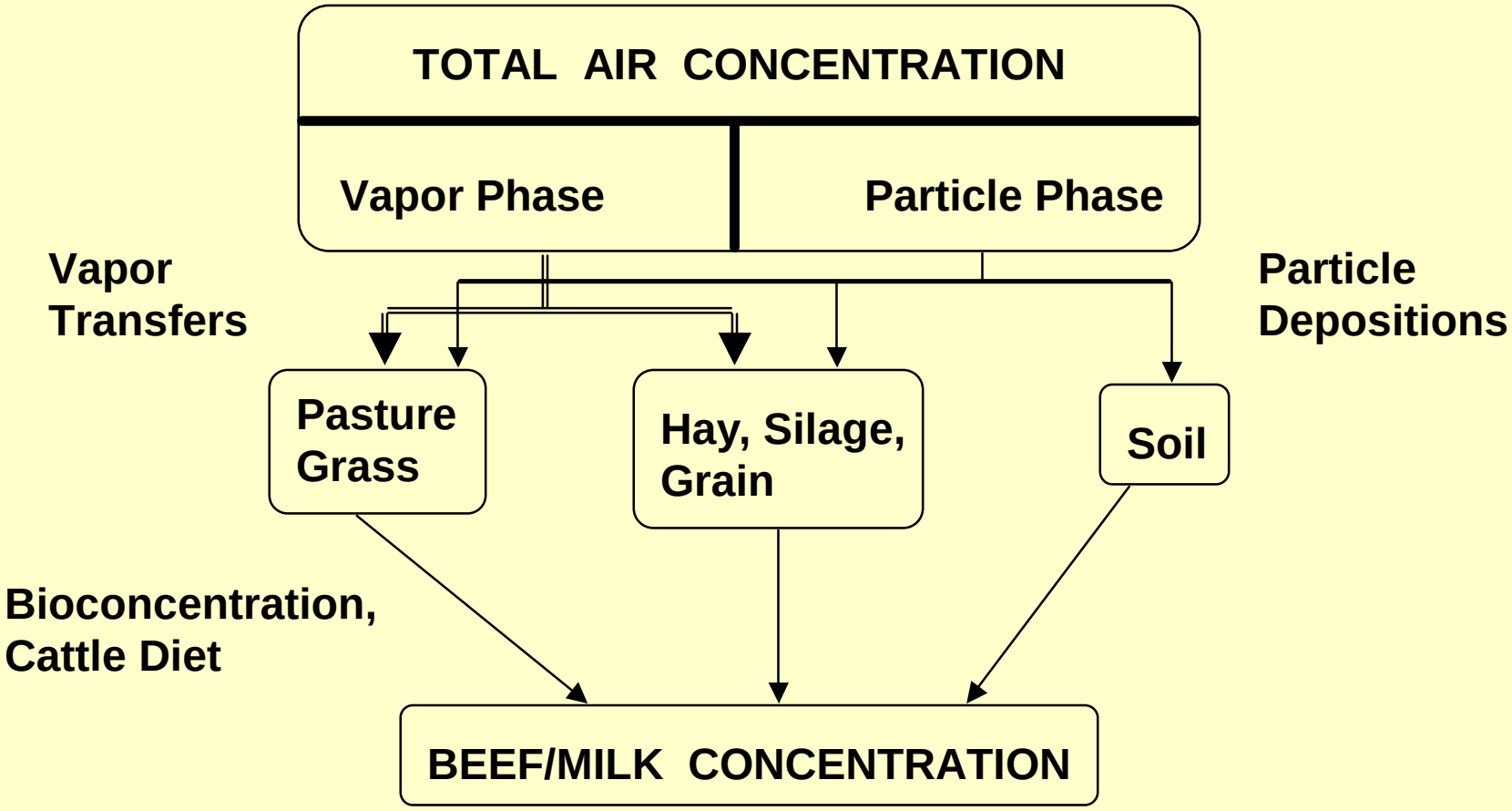
1. Used ISCLT 2 model runs for ambient air concentrations:
   - Assumed dry deposition = particle concentration * velocity of deposition
   - Assumed wet deposition = dry deposition
   - Assumed MACT reduces emissions by 99%

2. Assumed TEQs behaved as one compound; developed TEQ fate parameters based on parameters for 17 individual congeners

3. Used food chain models as described in the draft dioxin exposure document

Example - Columbus Incinerator

Air-to-Beef Model:



Example - Columbus Incinerator

Exposure Pathway	Contact Rates	Contact Fractions	Exposure Duration
Beef Ing.	100 g/day	100%	70 years
Milk Ing.	300 g/day	100%	70 years
Veg. Ing.	104 g/day	100%	70 years
Childhoold Soil Ing.	0.2 g/day 16 kg child	100%	5 years
Soil Dermal Contact	350 events/yr 1000 cm^2/event	100%	70 years
Breast Milk Ingestion	0.8 kg/day 10 kg child	100%	1 year

note: Mother's milk concentration estimated as function of mother's intake from beef and milk consumption

Example - Columbus Incinerator

- LOCATION OF THE EXPOSURE SETTING

The air concentration at the “subsistence farm” setting was estimated as the average X/Q from 9 actual dairy farms located between 5 and 12 miles away, times the emission rate.

X/Q: [Dioxin air concentration] / [Unit dioxin emission rate]

	X/Q
For screening assessment:	0.0036
At nearest of 8 farms:	0.0081
At MEI location:	0.055

Example - Columbus Incinerator

- RESULTS 1: Overall Exposure and Cancer Risk

Pathway	Exposure, ng/kg-day	Cancer Risk
Soil Dermal Contact	$6*10^{-8}$	$9*10^{-9}$
Inhalation	$6*10^{-6}$	$9*10^{-7}$
Soil Ingestion	$7*10^{-6}$	$1*10^{-6}$
Vegetable Ingestion	$1*10^{-5}$	$2*10^{-6}$
Milk Ingestion	$5*10^{-4}$	$8*10^{-5}$
Beef Ingestion	$1*10^{-3}$	$2*10^{-4}$

Example - Columbus Incinerator

- RESULTS 2: Comparison to Background

Pathway Exposure	Background Exposure pg TEQ/day	Columbus pg TEQ/day 1*	Columbus pg TEQ/day 2*
Inhalation	1.6	2.2	0.6
Beef + Milk	15	663	199
Breast Milk Ingestion	400**	3020	906

* Periods 1 and 2 correspond to no controls (6/83-1/94) and reduced emissions prior to MACT (1/94 to 1/97)

** 400 pg TEQ/day was finding in Draft Dioxin Reassessment assuming one year of breast-feeding and background concentrations in mother's milk